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A Literature Review on Wheelchair Products and Fitting

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A LITERATURE REVIEW ON WHEELCHAIR PRODUCTS AND FITTING

by

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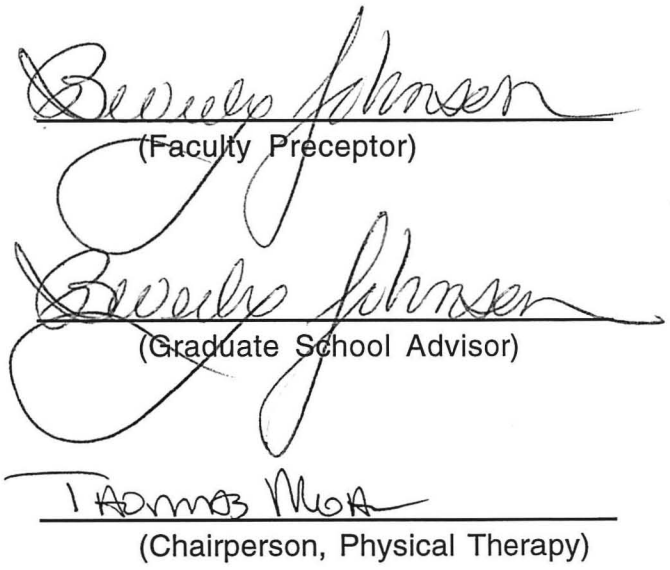
This Independent Study, submitted by Lee M. Werchau in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.



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ABSTRACT

Physical therapists are often involved in wheelchair prescription. An important factor when recommending or prescribing a wheelchair is proper fit. Proper wheelchair fitting is critical when attempting to get maximum independence, normalize tone in spastic or low tone clients, as well as decreasing bony deformities and pressure ulcers. Crucial measurements for wheelchair fitting include backrest height and seat width, depth, and height. To assure ultimate independence an individuals mental competence, ROM in upper extremities, cardiopulmonary health, and coordination must be evaluated prior to prescribing a wheelchair. Options to consider are the type of seat cushion, wheelchair frame, peripherals, and safety.

Seat cushions and support systems are important considerations in wheelchair prescriptions. The most common materials used for cushion and support systems include different types of foams, gels, and air pockets. Each cushion has different characteristics. These different characteristics include seat stability, cleanability, durability, cost and often, most importantly, the ability to distribute pressure evenly. Variations in wheelchair frames and peripherals may also have a large impact on the client's lifestyle. The above items should be considered to find the most desired balance for the client between mobility, stability, and protection against further morbidity.

The purpose of this independent study is to help physical therapists and other allied health professionals' make informed decisions when assisting in wheelchair prescription for their clients. This will be accomplished through a review of the current literature available on wheelchair frames, cushions, and peripherals as well as current seating and positioning practices.

CHAPTER 1

INTRODUCTION

The purpose of this independent study is to help physical therapists and other allied health professionals make informed decisions when assisting in wheelchair prescription for their clients. This will be accomplished through a review of the current literature available on wheelchair frames, cushions, and peripherals as well as current seating and positioning practices.

In 1986 over 340,000 wheelchairs were sold in the United States. Some of the diagnosis that may indicate a need for a wheelchair are cerebral vascular accidents, amputees, cerebral palsy, paraplegia, multiple sclerosis, rheumatoid arthritis, muscle and tendon disorders, cardiopulmonary disease, Parkinson's disease, epilepsy and other neurological or orthopedic conditions. Physical therapists are often involved in wheelchair prescription. For Many physical disabled individuals, correct wheelchairs and seating systems can significantly improve the quality of life at home, school, work, and leisure.[1,14]

Until recently there were relatively few products to choose from. Currently there are over 30 companies in the United States producing one or more style of cushion with a similar number of companies making wheelchair frames. In addition, there are also numerous motorized carts and scooters. The important factors to consider when prescribing a wheelchair may change from individual to individual. The top priority for a person with spinal cord

injury may be pressure management. Teenagers and business people may feel aesthetics and function are more important, while the elderly may only care about comfort. Safety and maximal independence are always overlying factors in all wheelchair prescriptions. To ensure ultimate independence and function a team assessment should be completed which would include an individual's needs, goals, mental competence, range of motion of all extremities, cardiopulmonary health, and coordination. This paper will concentrate on the physical aspects of the assessment. Psychosocial aspects, although important, go beyond the scope of this literature review. Options that are considered in this literature review are wheelchair fitting, seat cushion type, wheelchair frame, peripherals, and safety.[1,2,4,5,9,10,11,12,49]

An important factor when recommending or prescribing a wheelchair is proper fit. Proper wheelchair fitting is critical when attempting to obtain maximum independence, normalize tone in spastic or low tone clients, decrease bony deformities or decrease pressure ulcers.[1,2,4]

Seat cushions and support systems are important considerations in wheelchair prescriptions. The most common materials used for cushion and support systems include different types of foams, gels, and air pockets. Each cushion has different characteristics. These different characteristics include seat stability, cleanability, durability, cost and often, most importantly, the ability to distribute pressure evenly.[12,16,17]

The client's lifestyle and body build will impact the selection of options such as variations in wheelchair frames and peripherals. Wheelchairs can be varied by way of seat and backrest height, width, and depth. The chair may also be individualized with different wheels, hand rims, casters and types of

wheel locks. The above items should be considered carefully to find the most desired balance for the client between mobility, stability, cost, and protection against further morbidity.[1,2,4,5,18]

CHAPTER 2

MEASURING AND FITTING

When fitting for a wheelchair it is important to establish which accessories will be used, such as back inserts and seat cushions, since these will influence the final measurements. Having the client seated in a chair with similar peripherals would be an ideal situation. If it is not possible to fit the client in a similar chair many experts find that a solid chair with a back rest is preferred.[1,4]

Seat Width

Correct seat width is important for optimal function and comfort. If the seat width is too wide the client will have a poor biomechanical position. The wide wheelbase will make the chair more difficult to propel and an excessively wide seat width will also decrease the lateral stability of the client. This will cause poor lateral posture which will in turn force the client to either sacrifice mobility and/or stability.

A chair that is to narrow will limit access if the owner needs to wear bulky clothing or braces. A narrow chair may also cause pressure sores. To be sure the chair width is not to snug, one-two inches of space is allowed on each side of the trunk. (See figure One)[1,2,4]

Seat Depth

Seat depth is important in maintaining comfort and proper pressure

distribution. A generally agreed on measurement between experts is one-two inches between the anterior edge of the seat and the popliteal space. If the Anterior edge of the seat is to close to the popliteal fold, blood flow might be restricted in the lower extremities. In contrast, if the distance is to great between the popliteal fold and the anterior edge of the seat, interface pressure will increase.[1,2,3,4,5,6]

Seat Height

The seat height will have an impact on vertical positioning in relation to the handrim and footrest angle and length. Vertical positioning is the most important factor in seat height. For the average client, the vertical position will be at its optimum when elbow flexion is 120 degrees with the hands grasping the top of the handrim. To obtain optimum hight, the client should experience wheelchair propulsion with the seat both one inch higher and lower than the before mentioned position. This will allow the client to ascertain the most comfortable and efficient seat height for propulsion. (See force vector chart in appendix A)[1,2,3,4,5,6]

Foot Rest Length and Height

The function of the foot and legrest is to keep the feet off of the ground, maintain proper foot position, and to assist in pressure relief for the thighs. The footrests must have at least two inches of clearance from the ground to keep the foot rest from bottoming out on ramps and uneven surfaces. If the legrest is to short it will cause increased pressure on the bottom of the feet and the ischial tuberosities which would increase the chance of pressure ulcer. If the leg length is to long pressure will be increased on the popliteal fold causing a restriction in blood flow and increasing the chance of a deep vein

thrombosis.

The angle of the legrest from vertical should be as small as possible since an excessive legrest angle increases the overall wheelchair length. This makes it more difficult to maneuver in limited space. The angle of the legrest may need to be increased from vertical to decrease pressure on the feet, or if the front casters are not allowed to turn a full 360 degrees because of obstruction from the footrests.[1,2,3,4]

Back Height

The backrest height will influence trunk support and trunk mobility. The major factor in backrest height is the clients functional level. A client that has full function from mid-thoracic level and up should have a backrest that allows total freedom of the scapula. Backrests may go as low as the superior iliac crest. Most clinicians recommend the backrest height be measured to the inferior borders of the scapula for qualified clients. Backrests measured to the superior iliac crest are often avoided since studies have not been done to determine if low backrests perpetuate spinal deformities. Clients with high level involvement can still have relatively free scapular movement if the backrest has rounded corners. Clients that have decreased trunk control and little to no use of their upper extremities may need full back rests.[1,4]

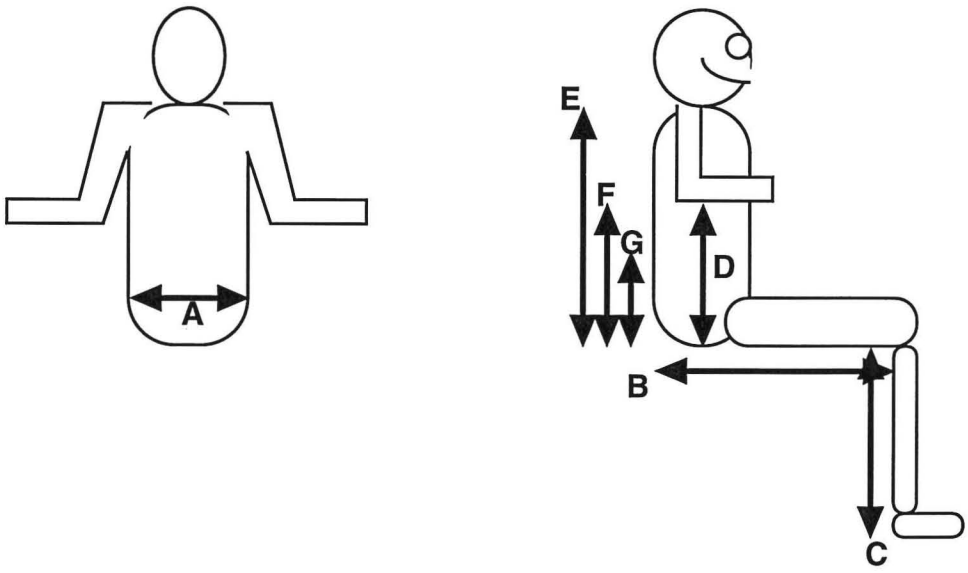
Back Width

The width of the backrest is not always an option. For clients that do have an option, the backrest should be the width of the clients trunk plus one inch. It is recommended that the back rest be contoured to increase the lateral stability and decrease the chance of spinal deformities.

Most canvas backrests have a natural contour. Clients that require extra lateral stability can be fit with custom molded backrests, or purchase reinforced side supports if they have a compatible wheelchair frame.[1]

Arm Rest Height

Most clients won't need armrests at all. If a client does need armrests they should be about one inch higher than the olecranon with the clients arms rested at the side. Armrests are used to support the arms, provide a surface for the client to push from to transfer out of the wheelchair or to achieve pressure relief over the buttocks, and provide extra lateral support if needed.[1,2]



A: Chair Width = Width of pelvis plus 2-4 inches

B: Seat depth = Back of seat to popliteal fold minus 1-2 inches

C: Seat height from ground = Popliteal fold to base of foot plus 2 inches

D: Arm rest height = elbow to seat plus 1 inch

E: Full backrest height = seat to top of shoulders

F: Backrest height to scapula= seat to inferior angle of scapula

G: Backrest height to superior iliac crest = Seat height to superior iliac crest

Figure 1. Wheelchair fitting diagram

Fore/Aft position in relation to axle

If the client is too forward in relation to the axle the rolling resistance will be increased because more weight will be placed on the front casters. The forward position will also decrease the clients ability to "pop wheelies" for curb jumping. If the client is too aft, the wheelchair may easily tip backwards. The advantages of having the client farther back include decreased rolling resistance and increased ease of "popping wheelies" for curb jumping. Each client will have different needs and preferences. It may be important for some clients to have a chair that can be easily adjusted as their skills develop and needs change.[3,4,6,7]

Table 1. Wheelchair fitting summery

Seat width	too narrow	difficulty getting into chair with braces or bulky clothing; Increased chance of pressure sores over trochanters; increased chance of thighs rubbing against the wheels.
	too wide	decreased lateral stability; decreased propulsion efficiency; decreased control
Seat depth	too shallow	increased pressure on ischial tuberosities and feet
	too deep	pressure across popliteal fold causing a decrease in blood flow
Back Height	too low	spinal instability; possible spinal deformities
	too high	restriction of upper extremity movement; decreased scapular motion
Footrest	too short	increased pressure on feet and ischial tuberosities
	too long	increased pressure over posterior thigh causing restricted blood flow
Seat height	long or short	decreased propulsion efficiency; (also see footrest)
For/Aft	too aft	increased chance of tipping position backwards;
	too forward	increased rolling resistance; difficulty reaching handrims

CHAPTER 3

WHEELCHAIR FRAMES

The frame of a wheelchair may vary greatly depending on the needs and characteristics of the user. An athletic client may require a lightweight sport chair that is strong enough to withstand the increased stress the chair would encounter. While another individual may need a frame compatible with a reclining backrest and elevating foot rests. In general, the client should be fitted with as simple a design as possible considering weight, cost, biomechanical efficiency and musculoskeletal status.[1,2,5,8,9,10,11]

Basic wheelchair frames

The basic frame is made from durable and relatively inexpensive mild tube steel with chrome-plating or stainless steel. Basic chairs can be purchased for less than $600. The basic chair is most often used in hospitals and nursing homes. Weight averages 50 lbs for tube steel and 40 lbs for stainless steel. The basic chair has push handles and a rigid standard backrest that is about 16 - 17 inches high from the seat. A reclining backrest is optional. Different frame colors are not available with standard chairs. The biggest advantage of the basic wheelchair frame is the cost.[1,2,9]

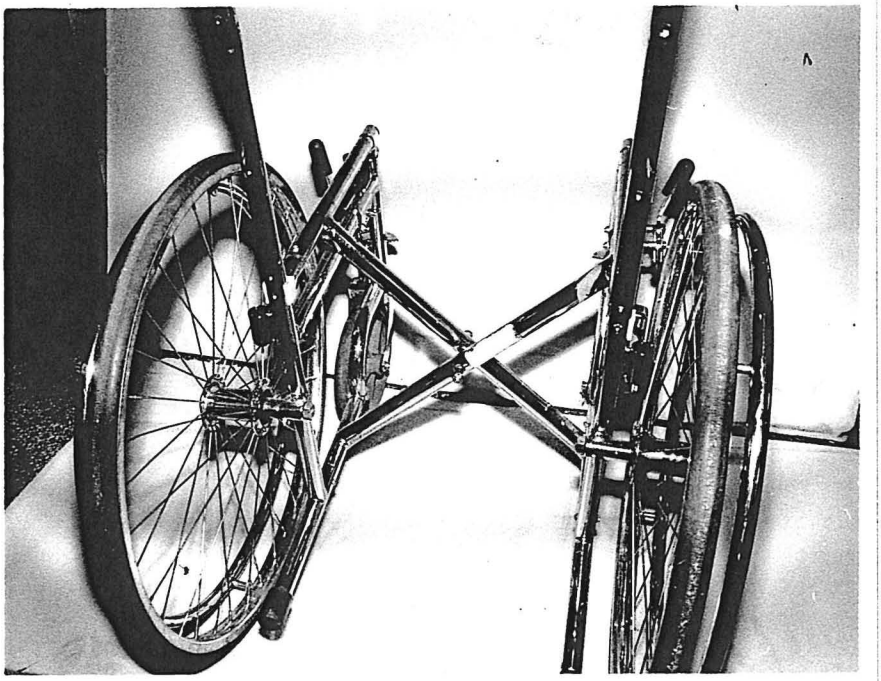
Light weight and sport wheelchair frames

The lightweight wheelchair frame has steadily become more popular in recent years. The lightweight wheelchairs are made of lightweight metals including titanium, aluminum alloys, and graphite. This also makes them much

more expensive than basic frames. Light weight wheelchairs cost between $1,500 and $3,500. The average total weight for the lightweight wheelchair is about twenty-five pounds. The lightweight makes the chair easier to handle and more efficient to propel. Lightweight chairs are available in a folding style or non-folding and can often be fit with the same options as the standard frame. The non-folding style is generally more durable and lighter than the folding frames. Non-folding wheelchair frames can be stored and transported in a car if the wheels can be removed and if the back is low. Lightweight folding chairs are either made with an "X" frame or a camp stool frame where the back folds down. The majority of the clients find folding frames more convenient when vehicle transport is necessary or if they have limited storage space. Folding frames also have disadvantages. The folding "X" frame wheelchairs are less durable than the non-folding, and the wheel alignment may change as people of different weight sit in the chair. As wheel alignment degrades, rolling resistance increases.

Push handles are an option with the sport chairs. Some clients find push handles more belittling as well as unnecessary weight. Lightweight frames can also come in many colors. Unpainted aluminum alloy frames need to be anodized leaving a charcoal gray or a dull silvery finish. If left unanodized the rim and frame would leave an oily gray film on clothing and skin. The draw back to painted or anodized wheelchair frames is that they are easily scratched and soon loose their new look.[8,9]

A



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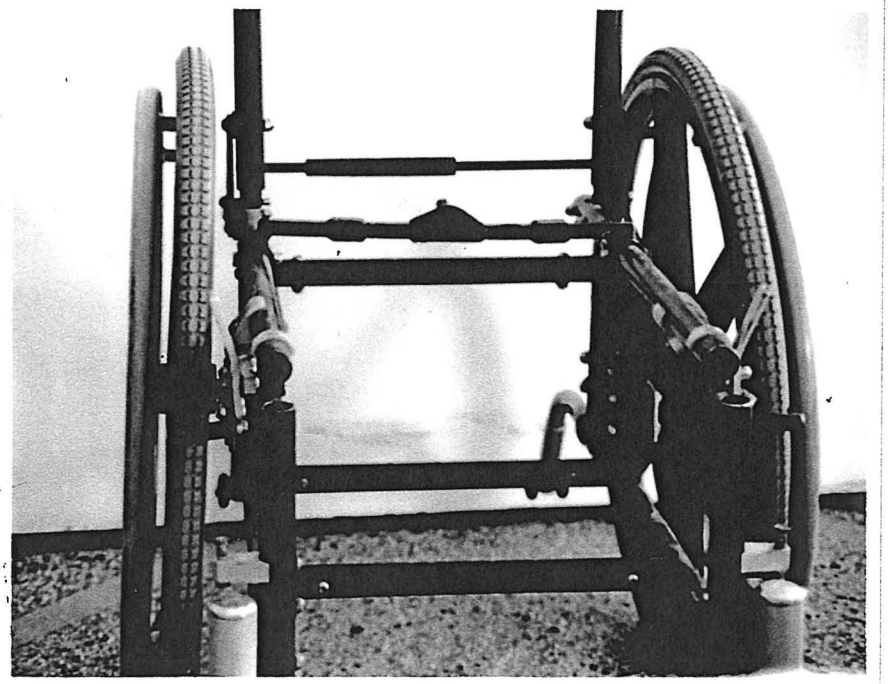


Figure 2. Wheelchair frames, A: Folding X Frame, B: Non folding

A

B

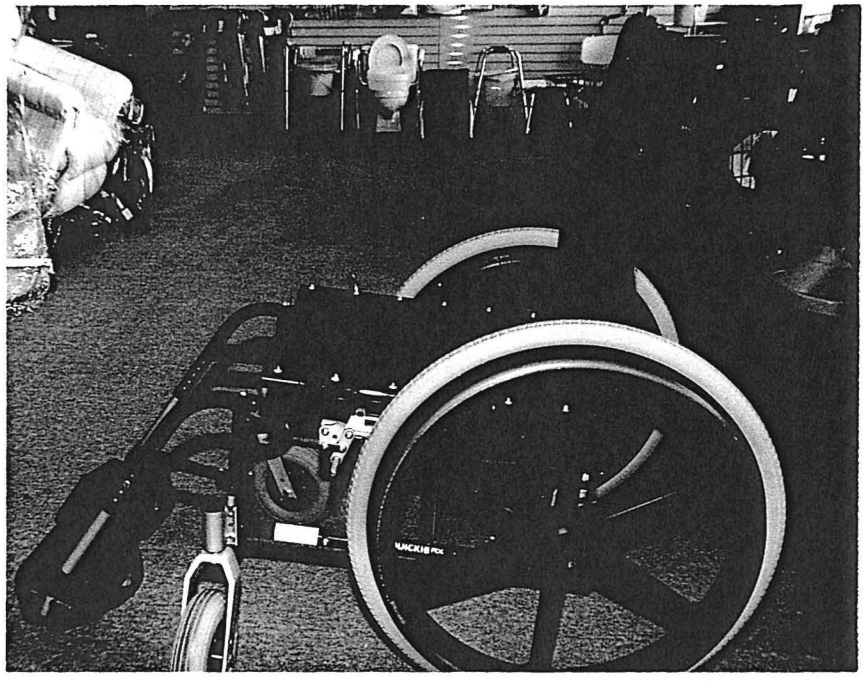


Figure 3. A: Standard wheelchair, B: Light weight wheelchair with high back rest.

Power chair frames

For the most part, power chair frames are adapted from standard chairs. Some companies are beginning to design chassis made for powered mobility, however, this option is not yet available in the US. Powered wheelchairs are a necessity for the individual that is unable to manually propel his wheelchair. A powered wheelchair can make an otherwise dependent individual independent. Powered wheelchairs also have disadvantages. The biggest disadvantage is initial cost and maintenance cost. Clients should expect to spend at least $2,500. Powered chairs also require specialized equipment and vehicle for loading and transport.

Powered wheelchairs come with many different drive options and driver interfaces for propulsion. These options and the mechanics of the powered wheelchair go beyond the scope of this paper. [1,2,11]

CHAPTER 4

WHEELCHAIR CUSHIONS

There are many different types of wheelchair cushions manufactured by over 30 companies as well as many on site fabricating facilities. A wide variety of materials are used, including rubber, synthetic foams, water, gel, air and various combinations of these materials.[12]

The importance of choosing the correct cushion for the client becomes apparent after reading statistics on the morbidity and mortality among wheelchair users secondary to pressure sores.[13,14,15,25] Seven to eight percent of the deaths among the spinal cord injured are directly related to pressure ulcers. Allman, Laprade, and Moell identified[15] "mortality rates ranging from 23% to 37% related to elderly patients being admitted to hospitals and institutions with pressure sores." In 1989 the National Pressure Ulcer Advisory Panel[14] estimated that a pressure ulcer may cost between $2,000 and $25,000 each. Garber and Dyerly[16] concluded that there is no such thing as a universal wheelchair cushion. Examiners must fully evaluate the clients social/daily life, orthopedic needs, neurological needs, and functional status. Other factors to consider when prescribing a wheelchair cushion are risk of pressure sores, cost, durability, and cleanability. Most individuals need modifications as their needs change and should be reassessed at 6, 12, 18, and 24 months after receiving the latest prescription. The two primary safety factors to be considered are

stability and pressure relief. A balance between stability and pressure relief must be found. Unfortunately, as stability is achieved, pressure relief is often sacrificed.[1,2,3,4] For many clients that are unable to achieve pressure relief through repositioning, protection against a pressure sore is the first priority. Pressure ulcers result from a combination of pressure, ischemia, and necrosis. Ulcers caused by shear forces are also considered pressure ulcers, although the cause is slightly different. Secondary causes of pressure sores are increased local temperature, protein and vitamin deficiency, fat loss, Anemia, and maceration from moisture, feces, and urine. Due to numerous factors which may contribute to pressure sores, considerations such as body positioning, body build, weight, ventilation, and heat transfer must be individualized.[12,13,15,16,17,18,19,20]

Pressure and time in the wheelchair are the most important considerations when choosing a cushion for a client. Many investigators have found that pressure and time are inversely related. As pressure decreases, time allowed in the chair without erythemia increases. Other investigators found that time in a static position was probably the most important factor in controlling pressure sores. These investigators were unable to find any cushions that were able to reduce seating interface pressure to below the capillary pressure in the sitting position. They also predicted that it may be impossible to ever create a cushion that would not inhibit capillary blood flow. Numerous companies have taken many different approaches to dealing with seating pressure and pressure sores. In many of the cases, studies by a non-biased source have not been performed to back the claims of the manufactures. Other investigators have performed studies with a single

product line from each category and generalized the results to similar cushions. Some of the characteristics may stay constant among all the products but others will vary since they may be made of different viscosities, shapes, or have different materials for covers that are claimed to alter the ventilation or shear forces.[13,16,17,18,19,20,21,22,23,26]

The following section will review some of the different items that are currently on the market. Information from manufacturers will be included in this literature review. Manufacturer information not supported by research will be identified. As stated earlier some of the cushion types are foam, water, gel, and air filled. The following paragraphs will discuss general characteristics of each category, identify a few popular brand names in each category, and discuss some specific differences as found through research or claimed by the manufacturer.[12]

Foam Cushions

Foam cushions are generally made from medical grade polyurethane or latex. Investigators have found polyurethane to be superior to the latex foams in durability, air circulation for removal of humidity, and support. The greater the density and thickness of the polyurethane foam, the more durable and supportive it is for the client.[12,16,27]

Foam cushions are superior to other cushions when it comes to original cost, maintenance/replacement, and handling. Foam cushions are much lighter than most other cushions, making them more convenient for transport and, unlike air, water, and gel cushions, foam doesn't need to be checked every day for pressure loss or punctures.[16,27,28] One study suggested that elderly

patients find foam more comfortable than gel or combination cushions.[24] Other benefits for foam cushions include ease of modification and increased stability. Investigators have not found a significant difference between seating pressure with foam cushions and other types of pressure relief cushions. They have found however that gel, air, and custom-contoured cushions (CCC) are significantly better in pressure ulcer prophylaxis than flat foam cushions.[16,17,24,28,29,30,33,34]

Foam cushions also have disadvantages. The first is foams' tendency to allow heat build up. Heat build up not only increases the local metabolism which increases the rate of ischemia, but is also uncomfortable for the client. Another disadvantage is foam's lack of durability and cleanability. Foam may be easily damaged by many types of cleaning solutions, heat, and light. Adding a protective cover to the foam may help increase foam's durability and cleanability. The life expectancy of foam cushion is limited, no foam at this time is able maintain its resilience past six months of use. Flammability is also a concern. Fire officials have banned or restricted the use of many varieties. Soft foams are generally more desirable because of its property to "wrap around" the client's buttocks. Although, if the foam is too soft for the client the foam will bottom out causing an increased peak interface pressure.

Custom-Contoured cushions (CCC) have been found to be superior to flat foam for pressure relief. The theory behind CCC is that tissue distortion is a factor in causing tissue damage. The decreased shear forces noted with CCC compared to flat cushions during loading may also result in relatively less tissue damage. In one preliminary study posture and balance also appeared to

improve for spinal cord injured persons. It was suggested that more studies be done before applying this conclusion to other wheelchair users.[30,31,32]

A few brand names of foam cushions include Pin Dot Products, Comfortex, Alimed, and Isch-Dish. Pin Dot foam cushions are made of self-skinning polyurethane foam. The product line consists of both custom contoured cushions and a modular system offering more than 34 standard sizes. All of the Pin Dot products are covered with waterproof cloth or vinyl.

Comfortex cushions consist of three layers of foam. The bottom two layers are made of polyurethane with a top layer of latex. Waterproof covers are not an option with comfortex cushions.[12]

Alimed uses a material called Temper Foam developed by NASA for space capsule seats. The manufacturer claims that the material is able to withstand "temperature and compression-rate sensitivity" better than other foams. Studies have demonstrated that Temper Foam can be an effective pressure ulcer prophylactic for the spinal cord injured population.[12,18]

Isch-Dish from Embracing Concepts, Inc. uses a fitted pocket system. The fitted pocket system is able to eliminate pressure over the bony prominences if fitted correctly. If the cushion is fitted correctly, authors concluded that pressure sores may become less likely. If the cushion is fitted incorrectly, pressure sores may become more prevalent. Studies also suggest that the cut out pocket in the rear of the cushion allows more ventilation which in return allows greater heat dissipation. The cushion itself is made of a polyurethane foam with a water proof film. A cover is then fitted to the shape of the cushion.[12,36,37]

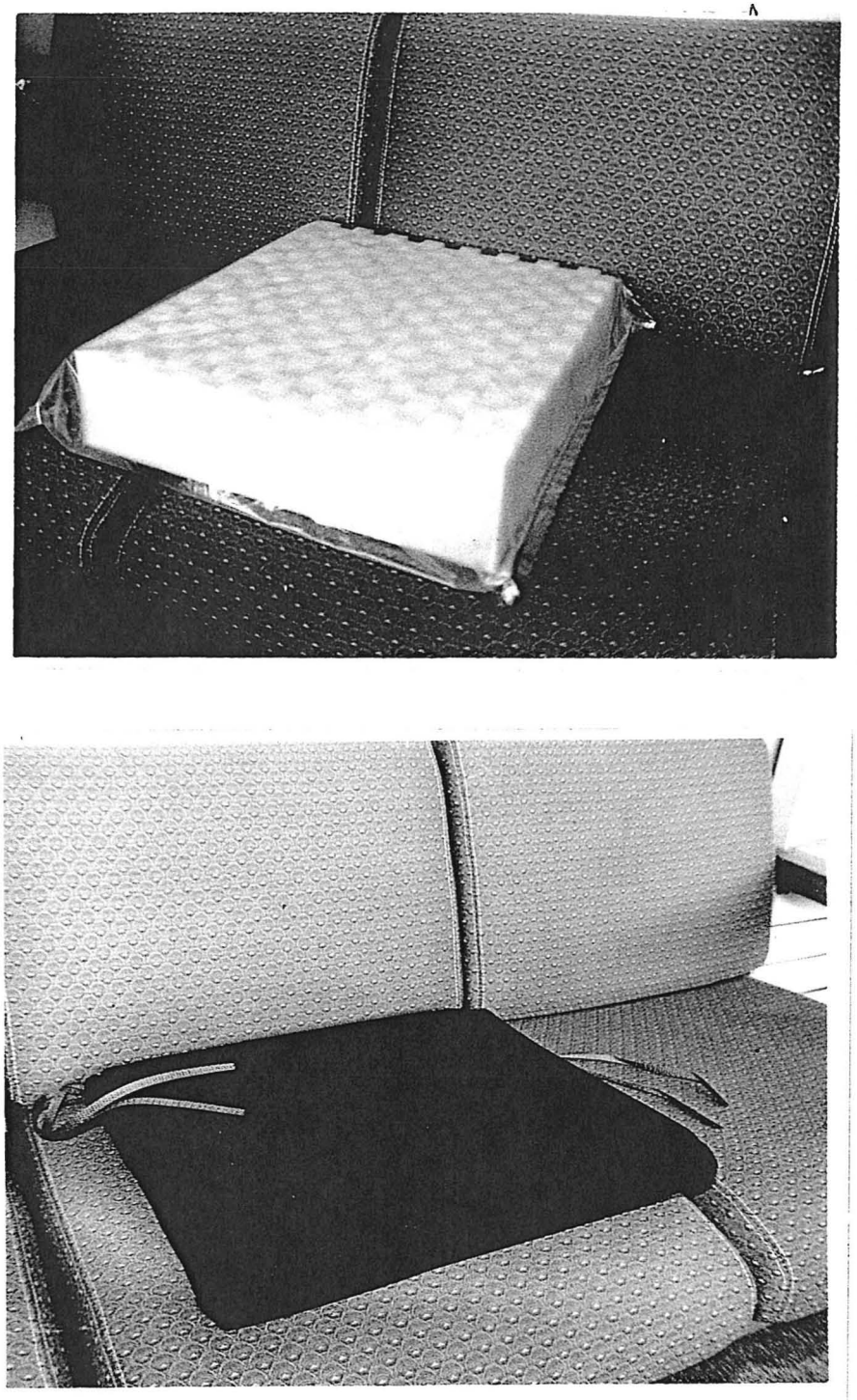


Figure 4. Foam cushions

Air cushions

Air filled cushions tend to be more popular among the spinal cord injured population. Many of the current cushions on the market today are much like the common camping air mattress and seat cushion. The cushions are composed of pockets that redistribute air as they are sat on to help equalize pressure. The air pockets can also be used to assist with seating posture and stability. The effectiveness of an air cushion is dependent on the air pressure inside. Both under and over inflation tend to decrease the ability of the air cushion to distribute weight evenly. Over inflation was generally better for reducing the seat-client interface pressures in all air cushions tested. Over inflation also has disadvantages. Air cushions in general are more difficult to transfer to and from and have decreased seated stability compared to most other cushions. This is excentuated with over inflation.[12,33,34,35]

Authors agree that air filled cushions can be an effective alternative to foam cushions for pressure sore prophylaxis but the client should be carefully evaluated for cushion client compatibility. Clients that will use an air filled cushion need to have a sense of responsibility to monitor the air pressure daily, resulting in maximum effectiveness. The client should also have equipment and a life style that would decrease the chances of punctures, cuts, and burns.

People with narrow wheelchairs may have problems with the cushion rubbing against the sides. Some wheelchairs may not accommodate the cushion, causing the wheel to rub against the cushion. Another problem associated with air cushions is the tendency to slip out between the seat and the back of the chair. The client needs to be aware of these and other potential

problems that may occur with their wheelchair. Another contraindication for an air cushion is smoking. Hot ashes could fall and burn a hole into the air pocket.

The benefits of air filled cushion include light weight, fire resistance, and easy to clean. The disadvantage of decreased stability may be compensated for by adding a contoured layer of foam beneath the air-filled cushion. Increased difficulty with transfers is not as easily compensated for and may be a factor in the clients final cushion choice.[12,33,34,35]

Currently some of the air-filled cushions on the market include Roho, Gaymar Sof-care, and Bye Bye Decubiti. Roho is currently the most popular among the air filled cushions. The Roho is made up of finger like flexible air cells. The manufacturer claims that the air cell design helps increase air circulation, thus dissipating moisture and heat. Current studies do not back this claim. The Roho company currently makes high profile cushions for the client with a high risk for pressure sores and a low profile for patients that are able weight shift or need greater stability. The literature is void of studies comparing the two designs for pressure relief or stability.

The Sof-care by Gaymar Industries, Inc. has also been found to be effective protection against pressure sores. Sof-care is made of twin layers of "interlocking" air cells.[12,34,38]

Bye-Bye Decubiti by Ken McRight Supplies, Inc. is a system of air pockets placed to decrease pressure over bony prominences. The manufacturer of Bye-Bye Decubiti has also stated that the design of the cushion "provides exceptional ventilation." Studies have not shown this to be true in comparison

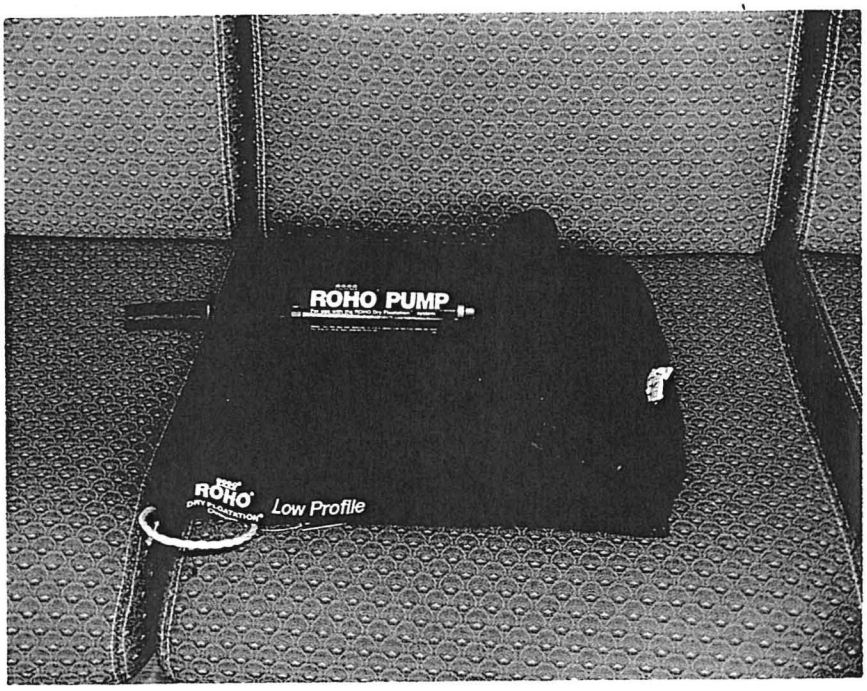
with other cushion types. This product has been shown to give effective protection against pressure sores. When compared to air, gel, and foam cushions, the Bye-Bye Decubiti demonstrates the lowest pressure reading over the ischial tuberosities. However the low pressure results from the Bye-Bye Decubiti will only be low if the ischial tuberosities are fit correctly in the built in depressions of the cushions. This limitation may result in the Bye-Bye Decubiti not being appropriate for clients that can not reposition themselves because of cognitive or physical disability.[12,34,35,39]

Flotation cushions

Flotation cushions include gel and water filled cushions. Many gel and water cushion manufacturers produce combination cushions that will use any combination of gel, water, air, and foam. Flotation cushions in general have been shown to be as effective against pressure soars as air cushions. The Jay cushion was found to be superior to polyurethane foam for pressure ulcer relief with elderly clients.[16,24,28,34,39]

The disadvantages of flotation cushions are similar to air cushions. The clients that utilize a flotation cushion need to be responsible so that punctures, cuts, and burns are avoided. Some gel products are made from a gel that is a finger jello like consistency. In these cases, guarding the cushion against puncture isn't as much of an issue. Another disadvantage of flotation cushions is the weight. This particularly becomes an issue when a client with decreased or impaired upper body strength is using a self propelled wheelchair. The flotation cushions also make it more difficult for clients to transfer in and out of the wheelchair. Cost can also be a disadvantage with flotation cushions

A



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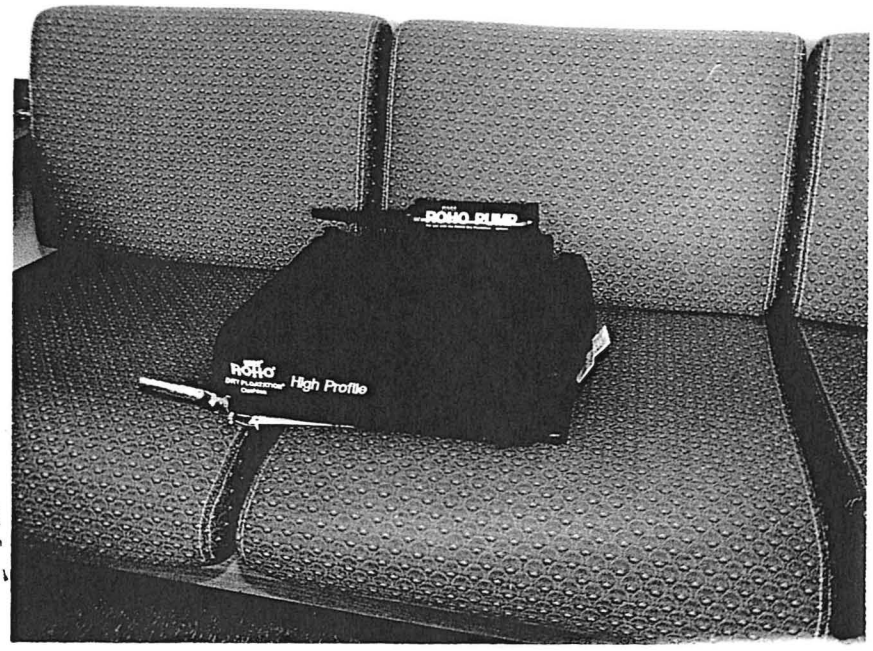
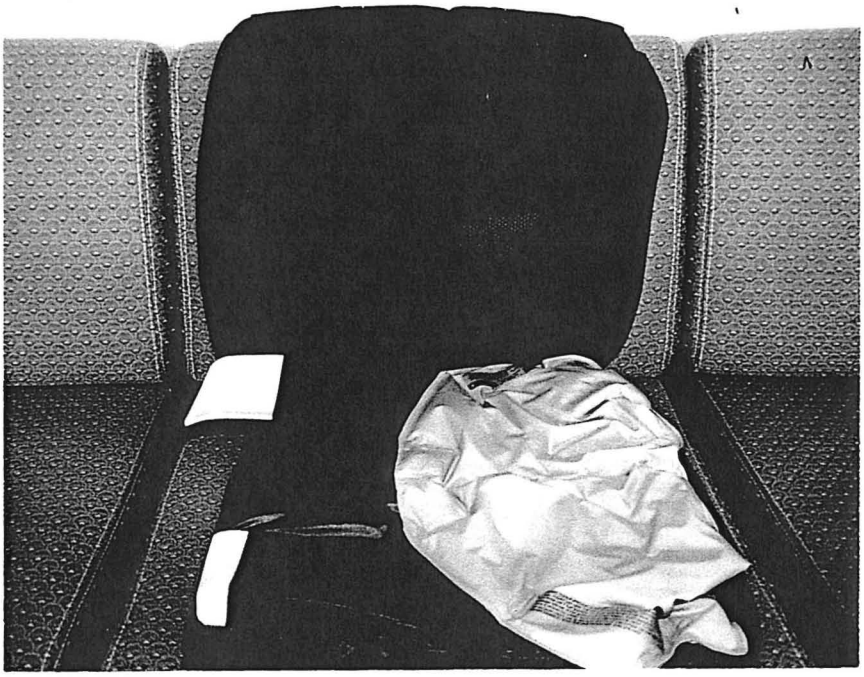


Figure 5. ROHO air cushions with air pump, A: Low profile, B: High profile

A



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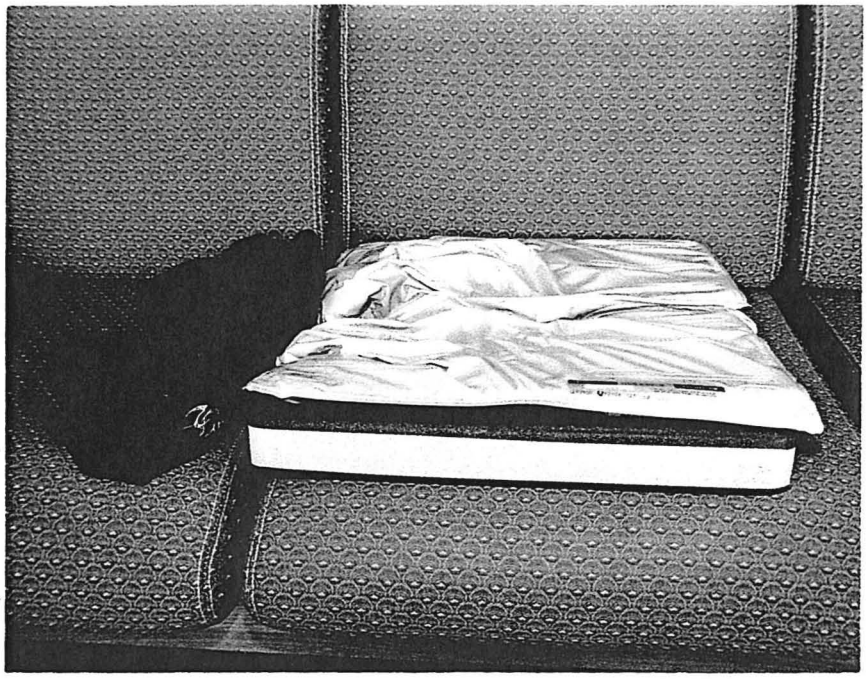


Figure 6. Jay combination gel and foam cushions, A: Jay Action, B: J-2

since they tend to be more expensive than foam or air cushions.

The "lack of memory" is an advantage of the flotation cushion. The cushion is able to form to a clients asymmetries or small foreign objects such as keys, and maintain its protective pressure relief. Another advantage is the ability to dissipate excess heat in the normal environment. This quality can also be a disadvantage. Gel and water both have properties that make them a potential hazard in cold weather. When gel and water pads are in contact with cold, the spinal cord injured population may be at risk for cold thermal injury. Although few cases of such damage have been reported, the investigators point out that cold thermal injury looks very much like a pressure sore. It was stated that without knowledge of the potential risk or a thorough history from the patient, the true etiology of the injury could be missed. Gel cushions also tend to become less pliable as temperature decrease although this has been found to be insignificant at normal ranges of room temperature.

Some brands of gel cushions are the Jay product line from Jay Medical,Ltd., and the Jobst Hydro-Float by Jobst Institute, Inc. The Jay line is currently the most popular of the gel cushions. The Jay original and Jay Active are the most popular cushion choice for the spinal cord injured. Both the Jay and the Jay Active have a contoured foam base with an overlay of gel packs. The packs are arranged so that high risk areas, such as the coccyx and ischial tuberosities, have a thicker layer of gel. The Jobst Hydro-Float is manufactured in much the same way. Both brands come with a washable and breathable outer cover.[12,16,17,33,39,40]

CHAPTER 5

PERIPHERALS

Wheels and Tires

Rolling resistance is primarily dependent on wheel and tire selection. The type of tire used will depend on the needs of the client. High pressure pneumatic tires are four times more efficient to propel than the solid gray rubber tires. Sport chair wheels are often cambered so that the top of the wheel is tilted inward. Cambering of the wheels allows easier access to the hand rims for propulsion. A camber of ten degrees does not have an effect on the rolling resistance of the wheelchair. On the other hand, if the tires are malaligned even a few degrees, the force required to propel the chair may double. If the client intends to use the chair on soft ground or grass, a wider pneumatic tire may be preferred. Wider tires are also less likely to get caught in cracks such as in elevator entries and side walk abnormalities. Pneumatic tires are also known for being lighter and having a smoother ride than the solid tires. Solid rubber tire benefits include very low maintenance and long wear time. Solid rubber does not need the air pressure to be maintained and the client doesn't need to worry about puncturing the tire. Current development of the solid synthetic tire is attempting to combine the efficiency and ride of pneumatic tires with the carefree benefits of the solid tire.[1,5,10,41,42]

The wheel of the wheelchair is the base for the tire to ride around. The wheel consists of the hub and spokes. It can either be made of wire spokes or

"mags." Mag wheels consist of the rim, spokes, and hub all molded as a single piece. Currently wire spokes, much like the front wheel of a bicycle, are the lightest. A disadvantage of wire spokes includes being easily bent with side impact. If a few spokes become loose from damage the wheel may hastily decay. Mag wheels can be made from aluminum, nylon, or graphite. Mag wheels have an advantage over wire spokes in that they need minimal maintenance and should last the life of the wheelchair. Disadvantages of the mag wheels are increased weight and unwanted increased flexibility. Some companies are considering the use of a disc wheel with a foam or honey comb hub much like those used by competition cyclists. These hubs would combine the rigidity and weight of wire spokes with the low maintenance of mag wheels.

The axle and bearings are also important features to address when considering a wheelchair prescription. The majority of the wheelchairs today use care free sealed ball bearings, however some manufacturers use inexpensive traditional ball bearings. The traditional ball bearings require adjusting, and maintenance to remain efficient. Traditional bearings also allow dust and other foreign materials into the bearings. This may be a disadvantage if the client will be going outside or has minimal assistance to aid in wheelchair maintenance. The axle takes on a great deal of stress during normal every day use. This is excentuated with active clients that ascend and descend curbs Independently. In order to know the strength of the axle the consumer should look up the test results in Wheelchair Standard ISO 7176/8.

The type of axle also determines whether the wheels are fixed to the chair or if they are the quick release style. The quick release style is beneficial when automobile travel and small storage is a priority. The quick release also

A

B

Figure 7. Light weight wheelchairs, A: Wire spoked wheels, B: "Mag" wheels

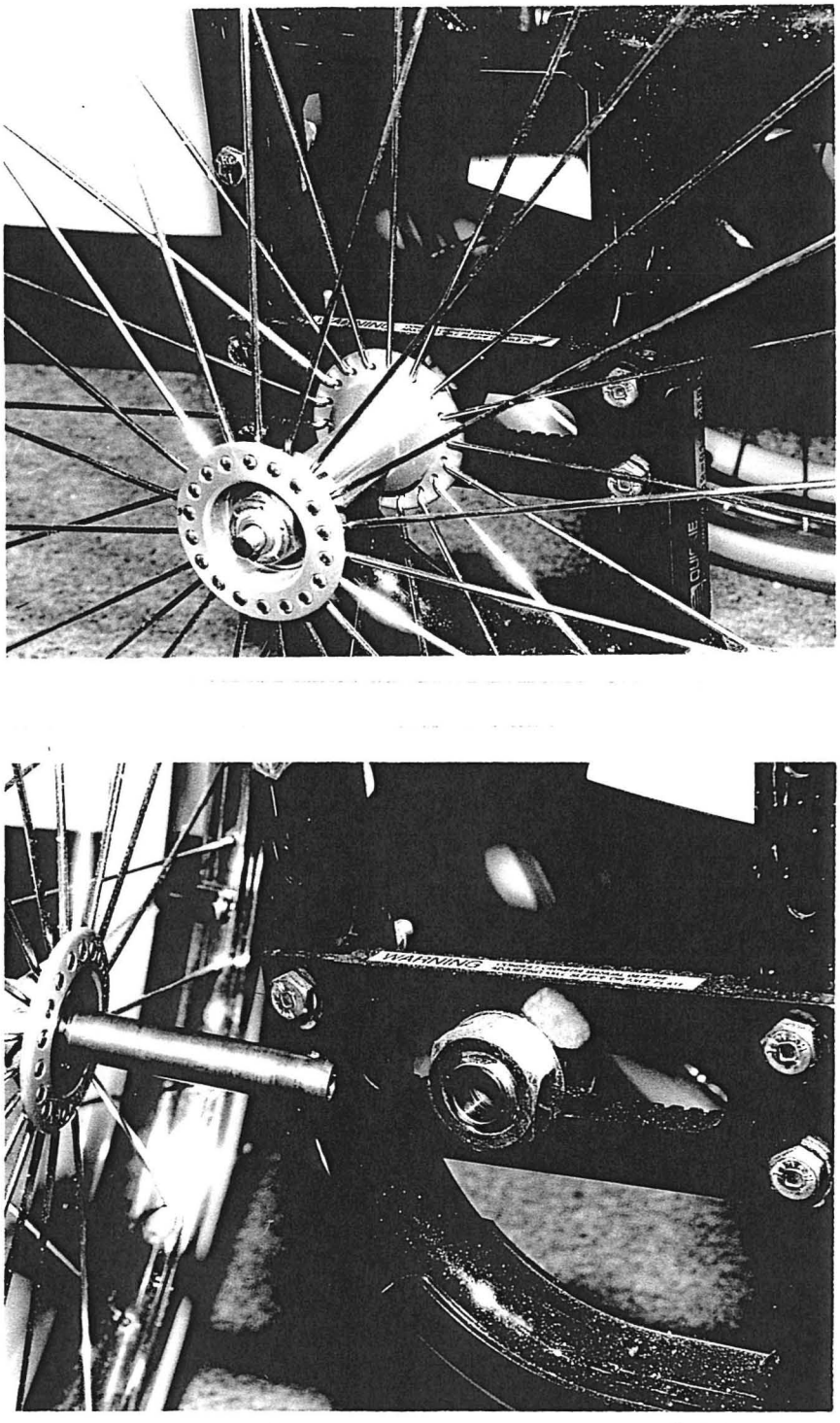


Figure 8. Quick release wheel with for/aft and up/down axle adjustment

allows the client to have an extra set of tires for changing conditions such as going from indoor use to outdoor use in soft dirt. Some manufactures build the frames to allow changing of the camber, axle height, and anterior/ posterior positioning.[1,5,10,]

Drive Systems

Hand rims are the means by which the majority of wheelchairs are propelled. There is a general feeling among professionals that metal hand rims should be used because they are able to dissipate heat caused by friction. Some of the metals used for the hand rims are aluminum, stainless steal, and Chrome plated tube steal. Aluminum is easily scratched and soon looses its "luster", and chrome plating can begin to flake with age. The chrome flakes can act as slivers lodging the palms of the hand or cause small cuts in the skin. Stainless steal is the metal of choice for metal hand rims because of its durability. Rubber coatings can be used to increase the friction of the hand rim and to add color to the wheelchair. Thicker rubber or foam covers may also be used if the client has poor grip strength. The thicker coating is beginning to be used much more to substitute for knobs on some hand rims.

Seat position in relation to the hand rim can make a significant difference with propulsion efficiency. Active clients with strong upper bodies often prefer lower seat position because it allows longer stroke lengths. This same position however would not allow a person with restricted shoulder extension or poor arm strength to efficiently propel the chair. Each client needs to be individually assessed to determine the most appropriate seat position. For the average person a medium seat height will be the most energy efficient. (See force vector chart in appendix A.)[1,2,3,4,5,6,45]

Other types of drive systems include foot propelled, lever propelled, and crank propelled. Foot propelled propulsion is mostly utilized by hemiplegics and the elderly. When fitting for a foot propelled chair it is important not to add two inches to the popliteal fold to floor measurement. Propelling a chair by foot consists of the client pulling the chair forward by flexing the knee with the foot on the floor.

Studies have demonstrated that both lever and crank propulsion are more efficient compared to hand rim propulsion. Unlike hand rim drives, seat position has little effect on propulsion efficiency with lever or crank drives. Lever drives either use push rods or chain and sprockets attached to the rear wheels to drive the chair. Crank drives generally utilize a chain and sprocket much like a rear bicycle wheel. The crank drives have been found to be the most efficient means of hand propulsion to date. The disadvantage to the crank system is that it is aestheticaly unacceptable to many clients. Another disadvantage is the increased cost and complexities of both lever and crank drives compared to hand rim chairs. At this time most lever and crank drives are produced in Europe with no US made models noted.[10,44,45]

Castors

The castor includes the wheel, axle, fork, and stem. Wheel sizes may vary from four to twelve inches in diameter. Propelling resistance increases inversely with caster radius. As the tire diameter decreases resistance increases. Most caster wheels are solid rubber or solid synthetic. It is difficult toe maintain the correct pressure in the pneumatic caster because of their small size. Axle bearings in the casters are almost exclusively sealed because the proximity to the ground allows dirt to easily reach the axle.

Figure 9. Pneumatic and solid caster tires with different styles of caster forks.

The fork of the wheelchair must be very strong. Ground forces and forces caused by head on and side impact from curbs and other obstacles can easily cause damage to the fork. The caster stem is also under an incredible amount of stress. The caster stem needs to be perfectly straight. If it is angled right or left the wheelchair will tend to trail in the same direction. If the top of the stem is tipped forward then the trail of the castor will be decreased which will cause the wheel to flutter. Flutter will cause resistance to greatly increase as well as increase the danger of losing control of the wheelchair and having an accident. Flutter tends to increase as tire weight increases, as speed increases, and as the castor trail decreases. Things that decrease flutter are wide tires and dampers in the stem of the caster. Dampers decrease flutter by increasing the friction between the frame and the stem.[1,2,4,9,49,50]

Front Rigging and Foot rests

Foot rests are used to keep the feet off the ground and to keep the posterior thigh raised from the anterior edge of the wheelchair seat. If the posterior thighs are resting to hard against the anterior seat it may hinder blood flow to the lower extremities. The front rigging on standard wheelchairs can be either fixed or removable. The removable riggings will often have a swing away option. The riggings are adjustable for rotation and length. The footrest is most often a rectangular plate and can have optional heel loops or foot straps. Front riggings for sport wheelchairs may have similar options as above, but on non folding models, often consist of a solid cross bar for a foot rest that is integral to the frame. The solid bar makes the wheelchair more sturdy. These foot rests are only adjustable in length. A decrease in maneuverability in small areas and difficulty getting close to counter tops are

Figure 10. Leg and footrests

disadvantages for both fixed front riggings and cross bar type foot-rests.[1,2,3,4,8,10]

Brakes

Currently the brakes of choice are either toggle type or lever type. Both standard and sport chairs can be equipped with either style. Many active clients with sport chairs opt not to have brakes. Even though sport chairs have the brakes fit low, many clients find that they get in the way during high speed propulsion. Some toggle brakes have been designed so they can be in a disengaged mode during propulsion to allow more space between the brake and the tire. The increased space decreases the chance of the break hindering full arm motion.

Running brakes are currently being used in Europe to slow decent on ramps or to slow from high speeds. The brakes are designed much like bicycle brakes. A survey done with paralyzed veterans demonstrates that paralyzed clients would equip their chairs with running brakes if available. [1,2,4,9,10]

Tipping / Anti-tipping devices

Tipping devices are extensions of the frame at the posterior inferior aspect of the chair. The tipping devices are placed so that a second person can easily tip the chair backwards as necessary for curb and stair negotiation.

Extensions can also be placed on the rear tip bars to act as anti-tipping devices. These are used to keep the client from tipping backwards. By using anti-tipping devices, more involved clients can take advantage of the aft positioning and the coinciding decrease in rolling resistance. The anti-tipping devices may be straight or curved. Curved anti-tipping devices have the

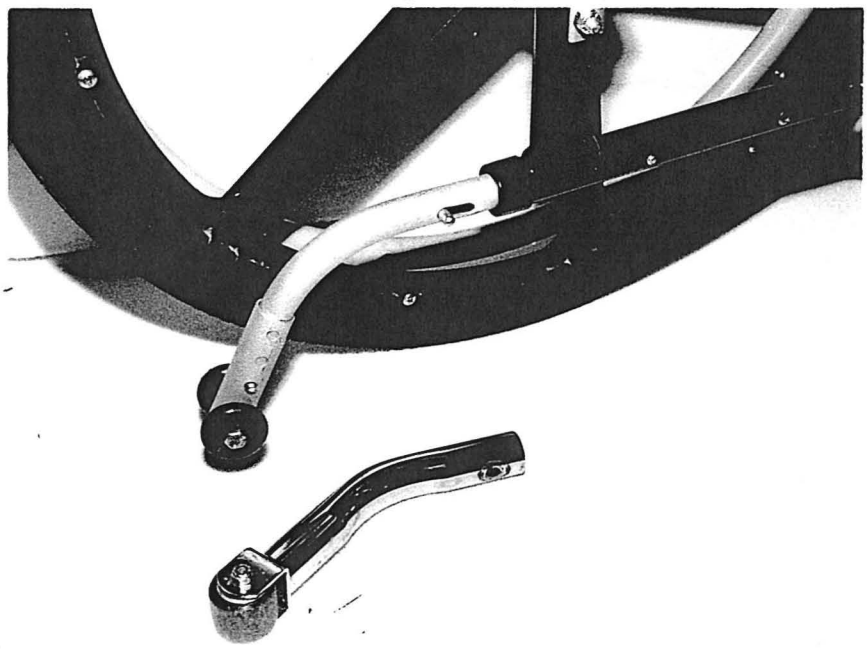


Figure 11. Anti-tip devices

advantage of being able to be temporarily turned upside down so that stairs and curbs can be negotiated easily. Anti-tip devices can also be made with small wheels at the ends.

Many active wheelchair users do not use rear anti-tip devices even though studies have shown that properly adjusted rear-antitip devices can prevent rear tip accidents. This is because the rear anti-tip devices also limit maneuverability in small areas and during curb negotiation. Because clients vary in the amount of rear anti-tip protection they need, some authors concluded that different anti-tip devices need to be assessed with each client prier to prescription.[1,2,4,46]

Armrests

If the rest of the chair has been fit correctly or if the client has good lateral stability, armrests are optional. Armrests are used to support the arms, provide a surface for the client to push from, and provide extra lateral support if needed. Armrests may also assist clients to achieve pressure relief over the buttocks by giving them a surface to push up from.

Armrests are either fixed or removable. Fixed armrests have the advantage of being lighter and less expensive compared to removable armrests. Fixed armrests also have the advantage of never being mislaid or lost. Most clients however chose removable armrests because of increased ease with transfers to and from the wheelchair. Removable armrests come in many styles and the client should have the opportunity to test a variety of styles to determine which is right for them. Both types of armrests are available in desk or full length models. Both models have advantages. Desk

models for instance normally don't have to be removed when the client rolls up to a table or Desk. Some clients however, such as those that are obese or have an increased lordosis, find desk models are more difficult to push up from.[1,2,4,]

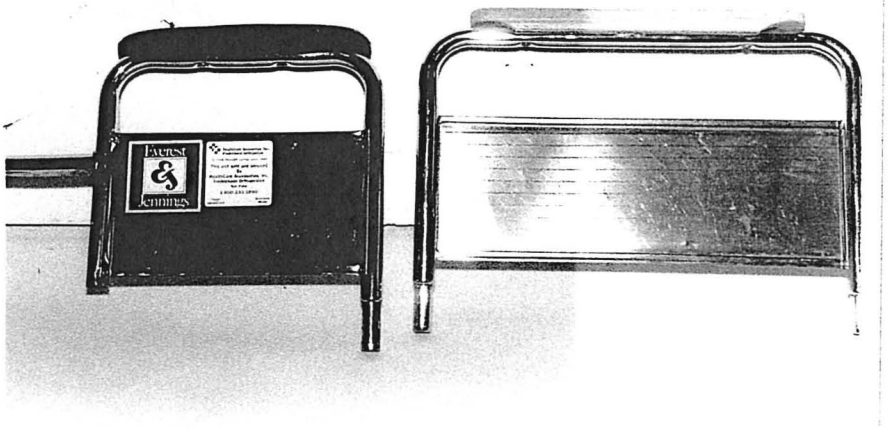


Figure 12. Desk model removable armrest and solid removable armrest

CHAPTER 6

WHEELCHAIR SAFETY

Wheelchair safety should be an important consideration for all clinicians prescribing a wheelchair. Over 26,000 wheelchair-related accidents that require emergency room assistance occur annually. More than 50 of these accidents will be fatal. A wide variety of causes have been reported. One older gentleman was attempting to cross the railroad tracks when his wheel got stuck and he was hit by a train. Another young boy reportedly was electrocuted when he accidentally propelled his chair into a fan. The majority of wheelchair related accidents result in small bruises and abrasions from tips and falls. Accidents also happen as a result of restraints, transfers, and thermal causes with thermal including heat injuries from fire and cigarettes and cold injuries as stated earlier with gel and water cushions in the winter.

Stability of the wheelchair is affected by many factors. The body build and shape of the client affects the stability of the wheelchair by changing the center of gravity. A bilateral AK amputee would have much less weight in the front of the chair. This would also decrease the backwards rotational stability, making it easier to tip backwards. By increasing the vertical position of the seat in any way decreases the wheelchair stability in all directions. This includes increasing the castor diameter and adding seat inserts without vertical compensation. Elevating the foot rests has been shown to increase the rear

rotational stability, but it is not known if this contributes to increased lateral tips. The most dramatic way of altering the rear and forward rotational stability is by changing the horizontal position of the seat in relation to the rear axle as talked about earlier. Anti-tipping devices may help decrease the chance of tipping backward, but these have been shown to fail if the rear rotational moment is too strong. They also decrease the independence of the skilled clients by making them dependent on others for curb and some ramp negotiation.

Many studies concluded that careful consideration of all safety issues be made for each individual prior to wheelchair prescription. This will give the client a balance between stability/safety and increased mobility.[46,47,48,49,50,51]

CHAPTER 7

CONCLUSION

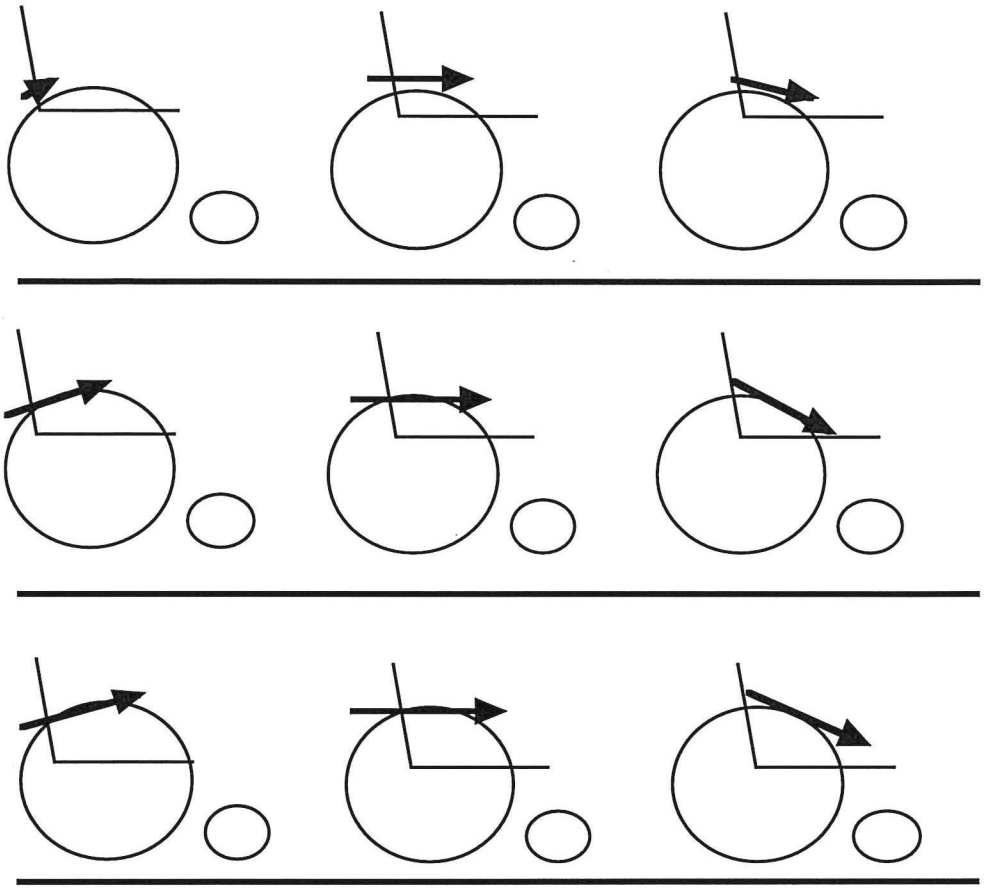
Wheelchairs are a necessity for non-ambulatory clients. A properly selected wheelchair and peripherals can make a completely dependent person independent. This will increase the clients self-worth and confidence as well as give the client a better quality of life. The cost of wheelchairs are variable. The least expensive basic wheelchair costs approximately $600 while a light weight wheelchair will cost between $1,500 and $3,500. Options will increase the cost ot the wheelchair from the above prices. An electric wheelchair can easily cost more than $3,000 depending on the clients needs.[1,2,4]

Wheelchair prescription deserves careful consideration of all the factors involved for each patient. Even patients with apparently similar circumstances may prefer very different systems. Prescription teams are important in proper wheelchair prescription. It is primarily the job of the Physical and Occupational Therapists to be the leaders in the prescription team. It is important that the client, therapists, physician, and all the other team members discuss the options fully and that proper measurements have been taken. This will ensure that the client receives a product that will satisfy his needs and wants as well as adapt to future needs. Factors to consider include function, safety, client satisfaction, and cost. The therapist and client should be aware of the type of reimbursement since it changes between insurance companies and state and federal agencies like Medi Care.[1,2,4,6,10,50,51]

Since technology is constantly on the move, therapists need to keep themselves updated on new products as they are introduced. The new products may be another step towards independence and a better quality of life for a client.[10]

APPENDIX A

Force Vectors for handrim drives at different seat heights



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